

1. A computer processor method of creating an audio multiplier control signal for controlling the dynamic range of a recorded audio work including an audio signal having an amplitude that varies over the time period of the work, said method comprising

5 receiving amplitude versus time values for said audio signal,
 determining an envelope of the amplitude of said audio signal,
 determining, for values of said envelope, respective minimum and maximum multiplication factors (MinMF and MaxMF) that can be multiplied times said values such that the products are above a predetermined minimum amplitude and below a

10 predetermined maximum amplitude of said dynamic range, and

 creating a control signal function of amplitude versus time such that all values of said control signal function at particular times are between respective MinMF and MaxMF values for said times, and such that segments of said control signal function have reduced slopes.

15 2. The method of claim 1 wherein said audio signals include digital audio samples.

 3. The method of claim 1 wherein said determining an envelope includes determining an envelope for the absolute values of the amplitude of said audio signal.

20 4. The method of claim 1 wherein said determining an envelope includes using a convex hull calculation.

 5. The method of claim 2 wherein said determining an envelope includes using a convex hull calculation.

 6. The method of claim 4 wherein said using a convex hull calculation involves traversing said amplitude versus time values with a moving range of data points.

25 7. The method of claim 6 wherein said range is greater than or equal to the longest wavelength of said audio signals.

 8. The method of claim 7 wherein said range is 750 samples or greater for a signal having a sampling rate of 44 KHz and a longest wavelength of 1/30 second.

 9. The method of claim 6 wherein data points on the trailing side of said range are dropped as the trailing edge of said range traverses said data points.

10. The method of claim 9 wherein data points within said range are popped as they fall below the envelope being extended to data points at the leading edge of said range.

11. The method of claim 1 wherein said creating a control signal function
5 includes using a first convex hull calculation for said MinMF values and a second convex hull calculation for said MaxMF values to identify line segments of said control signal function that are between said MinMF and MaxMF values and have reduced slope.

12. The method of claim 11 wherein said MinMF and MaxMF values are converted to logarithms prior to using said first and second convex hull calculations.

10 13. The method of claim 11 wherein said first convex hull calculation results in a low hull, and said second convex hull calculation results in a high hull, and a segment of the control signal function is determined each time that the low hull and high hull cross.

15 14. The method of claim 1 wherein said creating a control signal function includes using logarithms of said MinMF values and said MaxMF values and generating segments of a logarithm of said control signal function such that values of said logarithm of said control signal function are between said logarithm of MinMF and logarithm of MaxMF values, and such that segments of said logarithm of said control signal function have reduced slopes.

20 15. The method of claim 1 wherein said determining the envelope of the amplitude of said audio signal has an order of complexity of $O(n)$, where n is the number of audio signal values.

16. The method of claim 1 wherein said envelope has vertices, and said creating a control signal function has an order of complexity of $O(n)$, where n is the number of envelope vertices.

25 17. The method of claim 14 wherein said envelope has vertices, and said creating a control signal function has an order of complexity of $O(n)$, where n is the number of envelope vertices.

30 18. The method of claim 1 wherein each said amplitude value for said audio signal is examined at most a fixed number of times in said determining the envelope of the amplitude of said audio signal.

19. The method of claim 1 wherein said envelope has vertices, and each said vertex is examined at most a fixed number of times independent of the control signal lookahead in said creating a control signal function.

20. The method of claim 1 wherein amplitude values below a minimum threshold 5 value are taken as said minimum threshold value in said determining the envelope.

21. A computer processor method of controlling the dynamic range of an audio work including an audio signal having an amplitude that varies over the time period of the work, said method comprising

receiving amplitude versus time values for said audio signal,
10 determining an envelope of the amplitude of said audio signal,
determining, for values of said envelope, respective minimum and maximum multiplication factors (MinMF and MaxMF) that can be multiplied times said values such that the products are above a predetermined minimum amplitude and below a predetermined maximum amplitude of said dynamic range,

15 creating a control signal function of amplitude versus time such that all values of said control signal function at particular times are between respective MinMF and MaxMF values for said times and segments of said control signal function have reduced slopes,

20 using said control signal function to generate multiplication factors for respective times in said audio work, and

multiplying said audio signal values by respective said multiplication factors.

22. The method of claim 21 wherein said determining an envelope includes using a convex hull calculation.

23. The method of claim 22 wherein said using a convex hull calculation 25 involves traversing said amplitude versus time values with a moving range of data points.

24. The method of claim 23 wherein data points on the trailing side of said range are dropped as the trailing edge of said range traverses said data points.

25. The method of claim 24 wherein data points within said range are popped as they fall below the envelope being extended to data points at the leading edge of said 30 range.

26. The method of claim 21 wherein said creating a control signal function includes using a first convex hull calculation for said MinMF values and a second convex hull calculation for said MaxMF values to identify segments of said control signal function that are between said MinMF and MaxMF values and have reduced slope.

5 27. The method of claim 26 wherein said MinMF and MaxMF values are converted to logarithms prior to using said first and second convex hull calculations.

28. The method of claim 27 wherein said first convex hull calculation results in a low hull, and said second convex hull calculation results in a high hull, and a segment of the control signal function is determined each time that the low hull and high hull cross.

10 29. The method of claim 28 wherein said creating a control signal function includes using logarithms of said MinMF values and said MaxMF values and generating segments of a logarithm of said control signal function such that values of said logarithm of said control signal function are between said logarithm of MinMF values and said logarithm of MaxMF values, and segments of said logarithm of said control signal function have reduced slopes.

15 30. The method of claim 21 wherein amplitude values below a minimum threshold value are taken as said minimum threshold value is said determining the envelope.

20 31. Electronic apparatus for creating an audio multiplier control signal for controlling the dynamic range of a recorded audio work including an audio signal having an amplitude that varies over the time period of the work, said apparatus comprising an input to receive amplitude versus time values for said audio signal, a processor that determines an envelope of the amplitude of said audio signal and determines, for values of said envelope, respective minimum and maximum 25 multiplication factors (MinMF and MaxMF) that can be multiplied times said values such that the products are above a predetermined minimum amplitude and below a predetermined maximum amplitude of said dynamic range, creating a control signal function of amplitude versus time such that all values of said control signal function at particular times are between respective MinMF and MaxMF values for said times and 30 such that segments of said control signal function have reduced slopes, and an output for outputting values of said control signal function.

32. The apparatus of claim 31 wherein said processor is adapted to determine said envelope using a convex hull calculation.

33. The apparatus of claim 32 wherein said processor is adapted to use a convex hull calculation by traversing said amplitude versus time values with a moving range of
5 data points.

34. The apparatus of claim 33 wherein said processor is adapted to drop data points on the trailing side of said range as the trailing edge of said range traverses said data points.

35. The apparatus of claim 34 wherein said processor is adapted to pop data
10 points within said range as they fall below the envelope being extended to data points at the leading edge of said range.

36. The apparatus of claim 31 wherein said processor is adapted to create said control signal function using a first convex hull calculation for said MinMF values and a second convex hull calculation for said MaxMF values to identify segments of said
15 control signal function that are between said MinMF and MaxMF values and have reduced slope.

37. The apparatus of claim 36 wherein said processor is adapted to convert said MinMF and MaxMF values to logarithms prior to using said first and second convex hull calculations.

38. The apparatus of claim 32 wherein said first convex hull calculation results in a low hull, and said second convex hull calculation results in a high hull, and said processor is adapted to determine a segment of the control signal function each time that the low hull and high hull cross.

39. The apparatus of claim 31 wherein said processor is adapted to create a
25 control signal function by using logarithms of said MinMF values and said MaxMF values and generating segments of a logarithm of said control signal function such that values of said logarithm of said control signal function are between said logarithm of MinMF and logarithm of MaxMF values, and segments of said logarithm of said control signal function have reduced slopes.

40. The apparatus of claim 31 wherein said processor is adapted to replace amplitude values below a minimum threshold value with said minimum threshold value in determining the envelope.

41. A computer processor method of creating a reduced-slope series of line segments passing through a pair of Max and Min limiting functions specifying y values with respect to a variable x, said method comprising

defining said Max and Min limiting functions, and

using a first convex hull calculation for y values of said Min limiting function and a second convex hull calculation for y values of said Max limiting function to identify

10 line segments that are between said Min and Max values and have reduced slope.

42. The method of claim 41 wherein said Min and Max y values are converted to logarithms prior to using said first and second convex hull calculations.

43. The method of claim 42 wherein said first convex hull calculation results in a low hull, and said second convex hull calculation results in a high hull, and a said 15 segment of said reduced slope series of line segments is determined each time that the low hull and high hull cross.

44. The method of claim 41 wherein said defining said Max and Min limiting functions includes using logarithms of y values generated by said Min and said Max limiting functions, and said using first and second convex hull calculations involves 20 identifying line segments between said logarithm of Min and logarithm of Max values such that said segments have reduced slopes.